S1 Gravimetric $PM_{1.0}$ sampling and filter conditioning

Gravimetric $PM_{1.0}$ mass concentrations were determined by filter-based sampling following U.S. EPA procedures for fine $PM_{2.5}$ conditioning and weighing (U.S Environmental Protection Agency, n.d.). Filters and the analytical balance were housed in a dedicated conditioning room that maintained controlled temperature and relative humidity; all pre- and post-weighing was performed in this room to minimize environmental drift. Before sampling, filters were equilibrated in the conditioning room for at least 24 h, then weighed on a microbalance and recorded as m_{pre}. After sampling, loaded filters were returned to the same room, equilibrated for at least 24 h, and reweighed to obtain the post sampling mass, m_{post}. Field blanks from the conditioning room and test room were treated in parallel, and the mean blank mass change, m_{blank}, was subtracted from each sample mass gain. The gravimetric $PM_{1.0}$ concentration for each sample was calculated as

$$C_{PM_{1.0}} = \frac{(m_{\mathrm{post}} - m_{\mathrm{pre}} - m_{\mathrm{blank}})}{Q \times \Delta t} \quad (S1),$$

where Q is the volumetric flow rate (m^3 min^{-1}) and Δt is the sampling duration (min). For the calibration experiments, filters were collected over 10-minute intervals. Sensor data (SPS30 $PM_{1.0}$ and ADPD188BI blue-LED channel signal) were averaged over the corresponding 10-minute periods to obtain paired gravimetric-sensor points for the regression analysis.

S2 Low-cost sensor platform based on the Sensirion SPS30 and Analog Devices ADPD188BI

The SPS30 is a laser-based optical particle counter that detects light scattered by individual particles and uses onboard algorithms to report cumulative particle number concentrations $NC_{0.5}$, $NC_{1.0}$, $NC_{2.5}$, NC_4, and NC_{10} (cm^{-3}), corresponding mass concentrations of $PM_{1.0}$, $PM_{2.5}$, $PM_{4.0}$, and PM_{10} (µg m^{-3}), and a characteristic particle size (nm). According to the manufacturer, the SPS30 reports mass concentrations from 0 to 1000 µg m^{-3} with a resolution of 1 µg m^{-3}. The stated precision for $PM_{1.0}$ and $PM_{2.5}$ of ± (5 µg m^{-3} + 5 % of the measured value) µg m^{-3} and ±10 % of the measured value from 100 to 1000 µg m^{-3} (Datasheet SPS30 Particulate Matter Sensor for Air Quality Monitoring and Control). The ADPD188BI optical module was integrated to extend measurements to higher concentrations. The module includes blue and infrared emitters, matched photodiodes, and onboard signal processing for measuring bulk light scattering from particles above the chip. The ADPD188BI and an SHT31-DIS-B2.5KS temperature and relative-humidity sensor were mounted inside a custom Accumold chamber that shared an air path with the SPS30, ensuring that both optical sensors sampled the same aerosol (Analog Devices, 2020). All sensors were interfaced with a custom microcontroller board equipped with a real-time clock and microSD storage, which logged synchronized SPS30 and ADPD188BI signals for subsequent dynamic calibration. The

ADPD188BI infrared channel was excluded because its signal was dominated by noise under the experimental conditions.

S3 PSL sphere preparation and chamber experiments

Monodisperse PSL spheres were used to characterize the size-dependent response of the SPS30-ADPD188BI blue-LED pair. PSL stock suspensions were centrifuged and washed five times to remove residual surfactant. After each centrifugation step, the supernatant was discarded and replaced with 100 μL of 99.5 % isopropyl alcohol, and the suspension was redispersed using a vibrating shaker (Agrawal et al., 2024; Tryner et al., 2020). After the final wash, 1 mL of 99.5 % isopropyl alcohol was added to each centrifuge tube. The suspension was redispersed and then transferred to the nebulizer. The spheres were subsequently nebulized into the chamber.

Figure S1. Weighted Lasair particle-number bin fractions for aerosolized PSL spheres

Panels (a)-(e) show replicate chamber runs for nominal PSL sphere diameters of 0.49, 0.60, 0.72, 0.83, and 0.88 μm. A Lasair 1003 optical particle counter (Particle Measuring Systems, Boulder, CO, USA) measured the fraction of total particle counts in each size channel. Each bar was normalized to 100 %. For each PSL diameter, most counts occurred within one or two neighboring channels, and the modal channel shifted toward larger sizes as PSL sphere diameter increased. Counts in neighboring channels reflect the discrete channel boundaries of the instrument, while the overall patterns confirm narrowly distributed aerosols and separation among the tested PSL diameters.

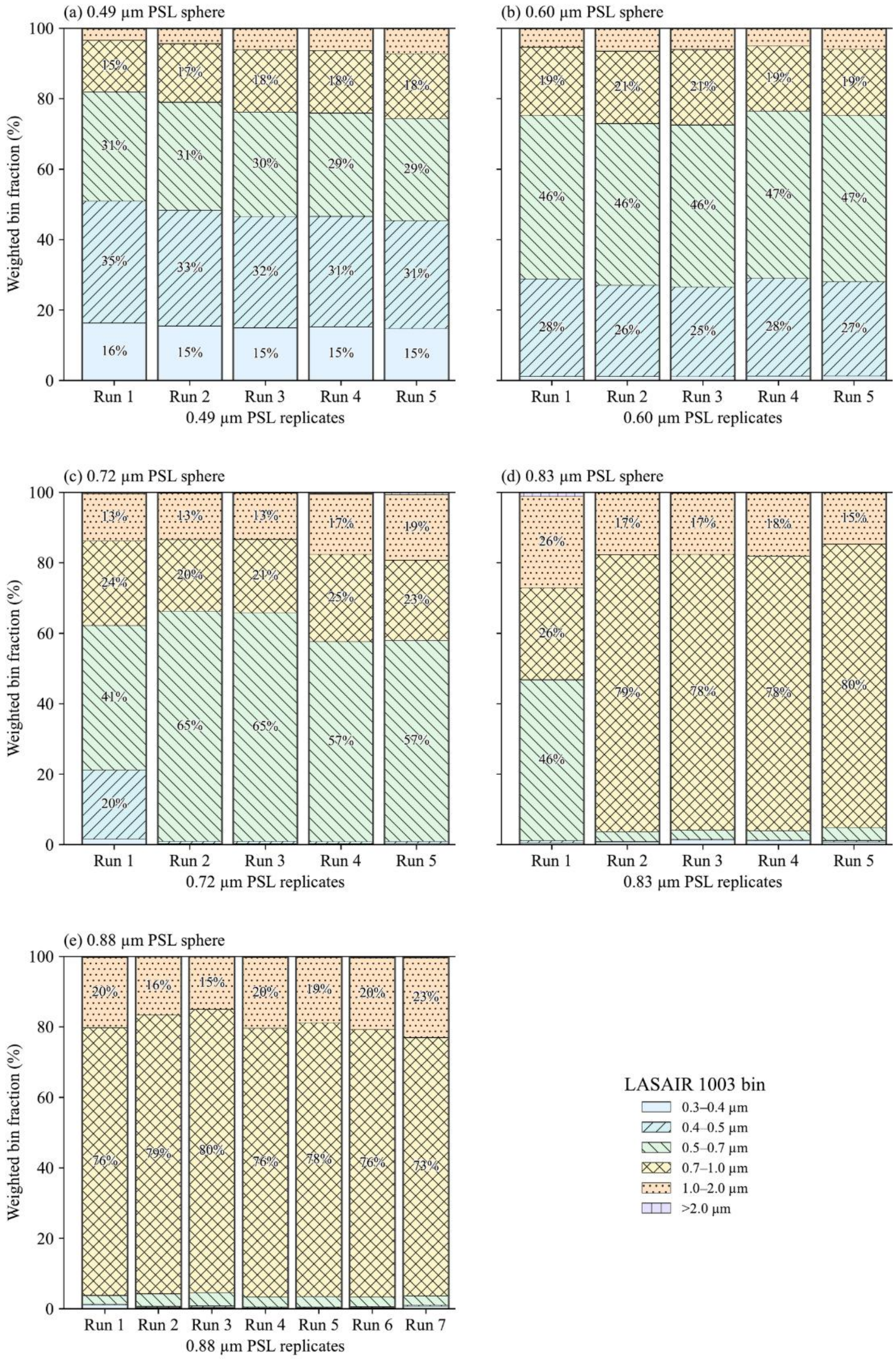

Figure S2. SPS30 particle number concentrations in the 0.5-1.0 µm range during PSL chamber experiments.

The bars show the mean cumulative number concentrations $NC_{<0.5}$ and $NC_{<1.0}$ and the derived number concentration between 0.5 and 1.0 µm, calculated as $NC_{0.5-1.0} = NC_{<1.0} - NC_{<0.5}$. As PSL sphere diameter increased, $NC_{<0.5}$ decreased and the derived $NC_{0.5-1.0}$ increased, indicating a shift toward larger particles within the submicrometer range. Because the SPS30 reports cumulative particle-number thresholds, this subtraction provides an approximate, rather than fully size-resolved, concentration for particles between 0.5 and 1.0 µm.

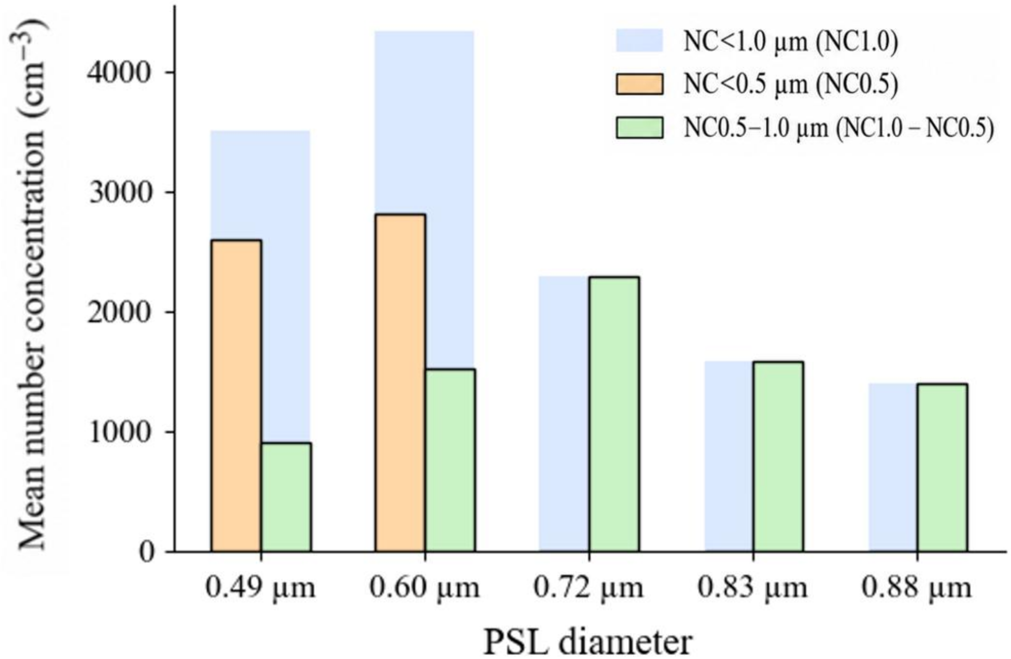

Figure S3. Size-resolved weighted particle-bin fractions for oak and pine combustion across increasing gravimetric $PM_{1.0}$ concentrations

Figure S3 shows the weighted particle-bin fractions for oak and pine under flaming/smoldering and smoldering-only conditions. Within each fuel burn category, individual burns are ordered from left to right by increasing gravimetric $PM_{1.0}$, so that the sequence of bars reflects progression from the lowest to the highest mass loading (up to ~1000 µg m^{-3} for flaming/smoldering burns and up to ~5000 µg m^{-3} for smoldering-only burns). At lower loadings, the finest bins (0.3-0.5 µm) dominate the weighted bin fraction, whereas the relative contribution of larger particles (0.6-2.0 µm) systematically increases as total $PM_{1.0}$ rises. Although this overall pattern was consistent, some burns with similar $PM_{1.0}$ mass showed noticeably different contributions from smaller and larger size bins, indicating that size distributions can vary even at comparable mass concentrations. All experiments were conducted in a chamber with temperature and relative humidity held approximately constant across burns.

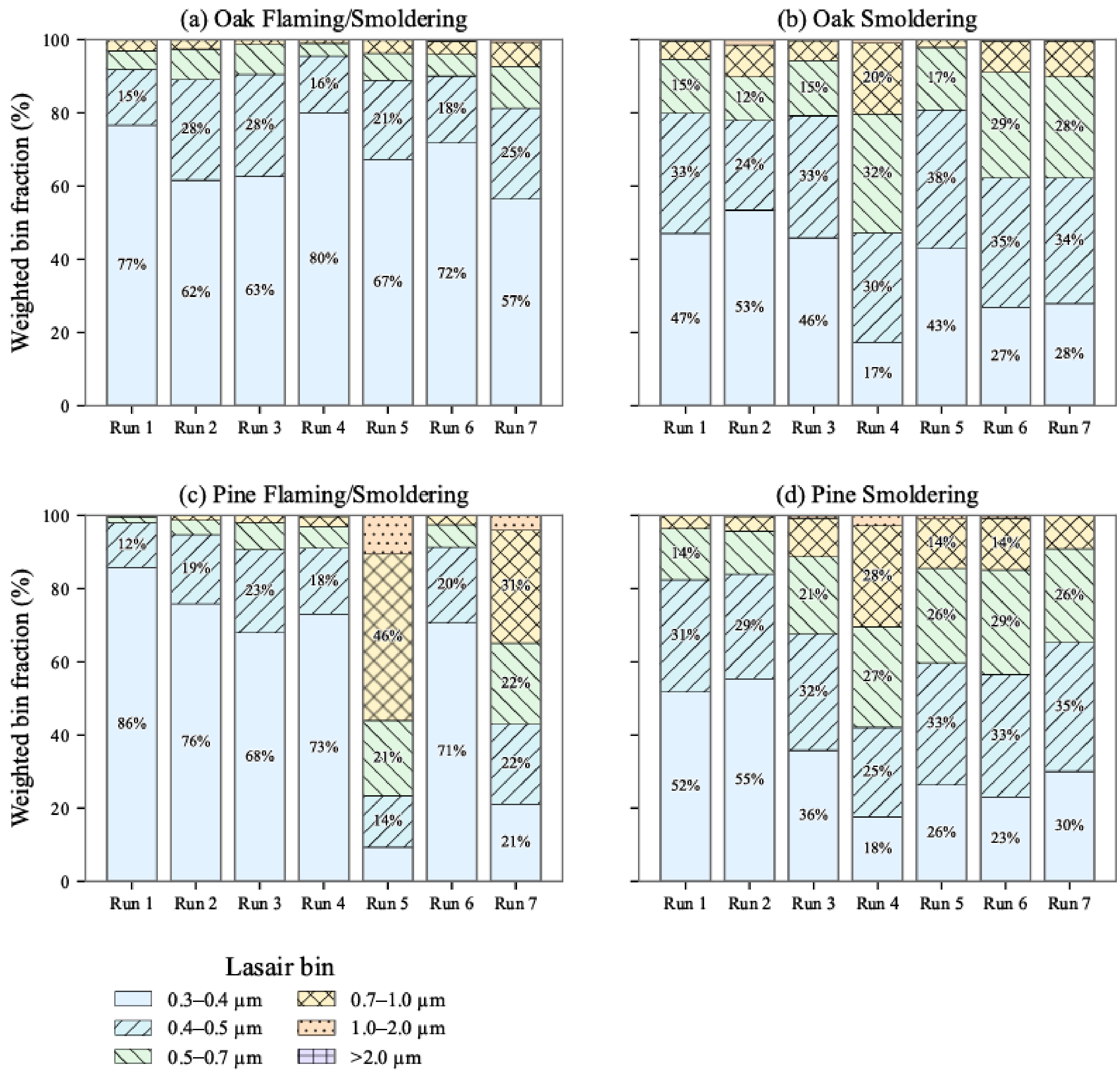

Table S1. Gravimetric PM$_{1.0}$ samples and corresponding sensor measurements

Table S1 lists gravimetric PM$_{1.0}$ mass concentrations for each combustion experiment together with the corresponding unadjusted DustTrak (model 8520, TSI Inc., Shoreview, MN, USA), SPS30 PM$_{1.0}$, and ADPD188BI blue-LED channel signal readings. These raw sensor values served as the input data set for the calibration analyses described in the main text. A DustTrak aerosol monitor was operated in parallel to provide supplementary real-time aerosol measurements. The DustTrak measurements were included for comparison and were not used to derive the dynamic calibration.

Combustion type	Gravimetric PM$_{1.0}$ (µg m^{-3})	DustTrak PM$_{1.0}$ (µg m^{-3})	SPS30 PM$_{1.0}$ (µg m^{-3})	ADPD188BI blue-LED (mA)
Bamboo	29.1	407.9	168.5	91.9

(Smoldering)	57.2	575.7	235.8	212.5
	108.5	712.9	356.2	157.4
	254.4	1017.1	478.9	171.2
	476.8	2045.0	898.1	377.9
	712.7	2682.5	1247.8	600.5
	1111.0	4875.8	1798.4	1206.3
	1395.2	5815.5	2075.0	1598.7
	2880.7	15074.0	4769.7	4245.8
Candle (Smoldering)	114.0	96.9	346.1	263.2
	251.0	230.1	681.4	367.8
	435.5	416.9	995.2	508.2
	660.0	630.2	1570.3	710.0
	1337.0	1252.4	3009.6	1374.7
Oak Wood (Smoldering)	57.3	78.8	19.8	116.8
	85.9	474.8	112.6	214.2
	542.2	1459.3	689.9	462.8
	913.9	2889.6	1289.0	736.6
	1459.3	4327.9	2006.4	1174.6
	1967.6	6519.9	2731.8	2010.5
	3311.5	14118.6	4847.2	3749.2
	4883.8	18367.4	5395.5	5132.5
Oak Wood (Flaming/Smoldering)	85.8	89.2	17.8	132.1
	109.5	346.9	44.1	198.7
	229.0	324.7	122.8	186.0
	400.8	712.0	258.1	267.3
	573.5	1286.6	589.8	386.4
	1237.1	2617.6	1189.1	627.1
	1378.5	3091.3	1393.6	722.2
Pine Wood (Flaming/Smoldering)	85.9	132.3	36.5	25.0
	143.0	271.9	46.7	127.6
	544.1	943.3	436.5	180.1
	715.6	1252.0	567.0	354.1
	886.3	1517.9	790.0	469.7
	1431.0	4180.6	1365.3	1033.9
Pine Wood (Smoldering)	28.6	83.7	31.5	121.2
	87.2	111.2	50.5	109.2
	171.7	198.4	106.8	103.0
	376.1	871.4	404.4	232.9
	545.2	1684.8	851.3	314.6
	948.3	2737.2	1330.2	623.9
	1395.8	4390.6	2344.2	1249.2
	2624.7	11389.9	4918.9	2630.0
	3539.2	16692.7	5315.6	3966.9

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